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Energy Saving Potential and CO_2 Mitigation Assessment Using the Asia-Pacific Integrated Model/Enduse in Thailand Energy Sectors

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Abstract

As a world has interconnected to the human activities globally, the energy demand is increasing rapidly. Such activities have also released tremendous amount of GHG emissions, especially CO_2 emissions. Nonetheless, Thailand is classified as a Non-Annex-I country without commitments on limitation of CO_2 emissions. However, Thailand has started to respond to such commitments. The objective of this study is to analyze a policy option to a policy maker in climate change issue by using the AIM/Enduse model. The AIM/Enduse model is an optimization linear programing approach. There are two scenarios created in this study. The current policy options have been applied in the BAU scenario via four energy demand sectors and energy supply sector. Efficient and advanced technologies have been introduced into the energy system in the PEAK CO_2 scenario. Such a scenario is expected to meet PEAK CO_2 emissions by 2035.

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Keywords: Peak CO_2, Energy system, AIM/Enduse, Low carbon technologies, Thailand

1. Introduction

Climate change is a very important issue nowadays. Various international organizations have focused on the increase of greenhouse gas (GHG) emissions, especially CO_2 emissions. The United Nations

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Framework Convention on Climate Change (UNFCCC) has convinced developed countries and invited developing countries to reduce GHG emissions for stabilizing GHG concentration in the biosphere. Moreover, the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report states that "It is very likely that all regions will experience either declines in net benefits or increases in net costs for increases in temperature greater than about 2-3^{o}C" [1]. Many studies have investigated GHG emissions for stabilizing the global mean temperature to be not greater than 2 degree Celsius. Van Vuuren et al. [2] suggested that the global GHG emissions may have to peak at 2020. The assumptions are very important factors to draw such a peak and such a reduction can be involved with the structural transformation [3].

Presently Thailand is classified as a Non-Annex I country without commitment for limiting CO_2 emissions at a certain level. However, Thailand has started responding to the international issues on mitigating GHG emissions. Many researches have studied on reducing CO_2 emissions by introducing Low Carbon Society pathway [4-10]. The objective of this study is to provide the policy options for mitigating CO_2 emissions via providing the advanced and efficient technology in the energy system, namely, power sector, industrial sector, residential sector, commercial sector and transport sector. Carbon Capture and Storage (CCS) is an important technology option for cutting down such emissions. Moreover, efficient technologies, high efficient and fuel saving engines in the residential, commercial and transport sector are also important for energy-saving and CO_2 mitigation. The objective of this paper is to study the possibility of transformation of Thailand's energy sectors to a low carbon society, which relies on such ambitious issues discussed presently.

2. Methodology

2.1. AIM/Enduse model

The AIM/Enduse model used in this study was developed by National Institute for Environmental Studies (NIES), Japan. The AIM/Enduse is based on the cost minimization linear optimization programing approach. This model starts from the flow of energy source, either primary or secondary energy, through the conversion of energy sources by using an energy technology to serve a final service demand for users or customers. The AIM/Enduse model can be utilized for forecasting the energy demand and CO_2 emissions either in the regional- and country-levels by evaluating the total system cost at an optimal solution [4-9, 11, 12]. Fig.1 shows the overview of AIM/Enduse model using in this study.

There are two scenarios which have been developed in this study, namely, the BAU scenario and PEAK CO_2 scenario in the study period of 2005-2050. The current policies, which are implemented for the Thai energy system, have been applied in the BAU scenario. Efficient and advanced technologies have been introduced into the energy system in the PEAK CO_2 scenario. Such a scenario could give a perspective to a policy maker to fully understand what will happen in the future.

3. Results and discussion

3.1. Energy consumption and CO_2 emission pathway in the BAU scenario

The BAU scenario assumes that the historical trends have been carried on until 2050. As the economic growth, the energy demand has been raised simultaneously. The primary energy used for the BAU scenario is given in Fig.2a. In the BAU scenario, primary energy used has increased from 77,421 ktoe in 2005 to 254,252 ktoe in 2050, and accounted for an annual average growth rate of 2.7%. Primary energy supply is forecasted to be dominated by fossil fuels.

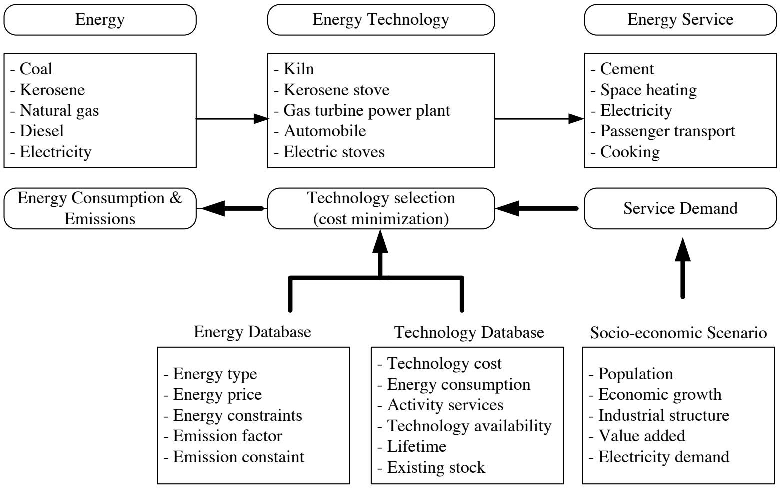

Fig. 1. Overview of the AIM/Enduse model.

Most of such a primary energy growth occurs from natural gas (including liquefied petroleum gas; LPG and compressed natural gas; CNG). Since, Thailand has mostly used natural gas for electricity generation, and it is accounted for 83.5% of total natural gas consumption in 2005 and continues to grow at 3.1% (Fig.2a). Such high natural gas consumption can be clearly understood that most of the power plants have been presently utilized by combined cycle power plants using natural gas as a main fuel. Transportation also plays a vital role on primary energy consumption. Logistic transportation has mostly consumed diesel. Diesel consumption has been increased from 12,704 ktoe in 2005 to 22,616 ktoe in 2050 and accounted for an average growth rate of 1.3% per annum including diesel oil and diesel blended with 5% bioethanol (B5). The reason of such an increasing is that the road transport has been a major mode in Thailand. Diesel has been continued constantly due to a high level of public transport and logistics transport. Moreover, Thailand's government also subsidized the diesel price for supporting public transport and logistics transport. Coal consumption is lower than natural gas consumption due to public acceptance and coal has emitted pollutants higher than natural gas. Furthermore, coal has been used for feed stock in thermal power plants and heating for non-metallic industry. Fuel oil and jet fuel have been escalated from 8,698 ktoe in 2005 to 19,242 ktoe in 2050 and has risen about 1.8% annually. Air and water travel has played a vital role in jet fuel and fuel oil consumption.

Bio-energy, including both traditional biomass and modern biomass, has been increased from 11,821 ktoe in 2005 to 25,278 ktoe in 2050 and accounted for an average growth rate of 2.1% per annum. Bio-energy consumption has been dominated for heating in industrial sector especially food and beverage industry, chemical industry and non-metallic industry. Fuel wood, charcoal and paddy husk have been wildly used for cooking in rural area in the residential sector. Intermittent renewable energy source (IRES) namely; wind and solar and hydro power have been used for electricity generation. Renewable energy has been increased from 502 ktoe in 2005 to 2,426 ktoe in 2050 and accounted for an average growth rate 3.6% per annum.

Fig.3a has depicted the sector-wise final energy consumption namely; industrial sector, residential sector, commercial sector and transport sector. However, electricity generation from power sector has already been included in each sector. The final energy consumption has risen constantly from 58,849 ktoe in 2005 to 181,828 ktoe and accounted for an average growth rate of 2.5% per year. All heating systems using coal and biomass have dominated in the final energy consumption in the industrial sector. Shares of coal and biomass in final energy consumption will be accounted for 53% in 2050. Likewise, motor and cooling system, including fans, conveyor belts and chillers, have been accounted for 28% in 2050. Gasoline car and diesel car, therefore, continuously have been dominated in the final energy consumption in the transport sector. Some of the gasoline cars use gasoline blended with 10% ethanol and some diesel cars use diesel blended with 5% biofuel. Lighting and cooling system, have been dictated the electricity consumption in the commercial sector and the residential sector. The combined electricity demand has been increased from 5,769 ktoe in 2005 to 14,570 ktoe in 2050 or approximately increasing 3 folds.

The total CO_2 emission of all energy sectors significantly increases in BAU scenario. Total CO_2 emission has been augmented from 193,578 kt-CO_2 in 2005 to 672,396 kt-CO_2 in 2050 (Fig.5a). This situation implies that no new policies and advanced technologies have been implemented. The power sector has generated the highest CO_2 emission. CO_2 emission from power sector has been essentially dominated by natural gas. Since, electricity generation system in Thailand has relied on combined cycle power plants. Likewise, the transport sector is the second largest CO_2 contributor. Thailand transportation has relied on road transport since road network has been covered the country entirely. Most CO_2 emissions in the transport sector come from diesel engines.

3.2. Energy consumption and CO_2 emission pathway in the PEAK CO_2 scenario

Fig.2b shows that the transformation to low carbon technologies leads to substantial changes in the total primary energy consumption when compared to the BAU scenario. The total primary energy consumption has increased from 77,421 ktoe in 2005 to 213,627 ktoe in 2050 under PEAK CO_2 scenario and accounted for an annual average growth rate of 2.3%. Clearly, it can be seen that the total primary energy has decreased by 16% in 2050 when compared to the BAU scenario. It can be observed that there is fuel switching. The fossil fuel share has been dropped from 88% to 74%, whilst the renewable energy share including bio-energy and IRES have been increased from 12% to 26% in 2050 compared to BAU scenario. The natural gas and gasoline reduction in primary energy consumption is the largest and

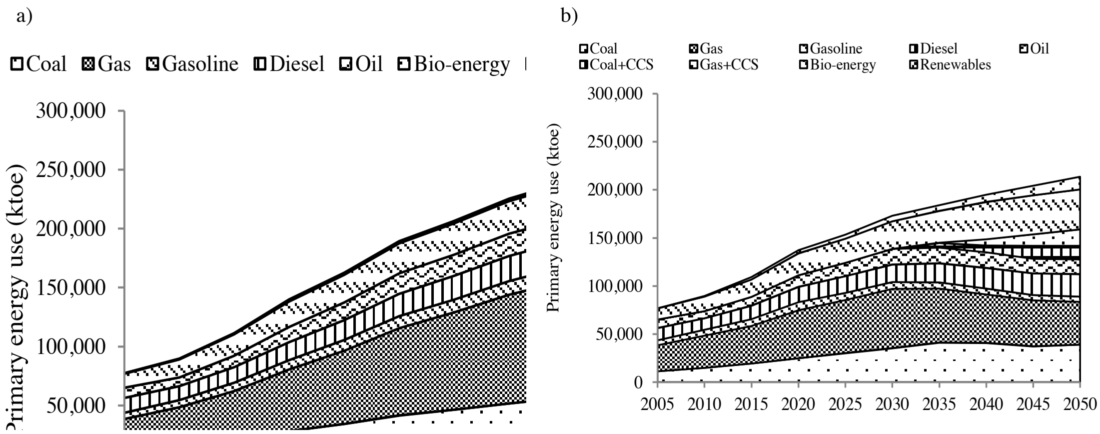

Fig. 2. Primary energy used in a) BAU scenario and b) PEAK CO_2 scenario. Note: Coal includes coal and lignite; gas includes natural gas, liquefied petroleum gas (LPG) and compressed natural gas (CNG); gasoline includes gasoline, gasoline blended with 10% ethanol (E10), gasoline blended with 20% ethanol (E20, PEAK CO_2 scenario) and gasoline blended with 85% ethanol (E85, PEAK CO_2 scenario); diesel includes diesel, diesel blended with 5% bioethanol (B5), diesel blended with 10% bioethanol (B10, PEAK CO_2 scenario) and diesel blended with 20% bioethanol (B20, PEAK CO_2 scenario); oil includes jet oil and fuel oil; bio-energy includes traditional biomass; renewables include hydro power, wind power, solar power and municipal solid waste (MSW).

accounted for 58% and 57% reduction, respectively. Such a reduction of natural gas has been significantly occurred in the power sector and the industrial sector using efficient boilers and waste heat power generation from 2015 onwards. The remaining natural gas consumption has been primarily used in electric power generation using CCS. Likewise, flex-fuel sedan cars using gasoline blended with 20% ethanol (E20) and gasoline blended with 85% ethanol (E85) have been introduced after 2015 onwards. Diesel oil consumption has been slightly increased by 3% in 2050 when compared to the BAU scenario because the results of the mode shift for private transport to public transport. However, the share of efficient diesel engine using diesel oil blended with 5% bio-oil (B5), diesel oil blended with 10% bio-oil (B10) and diesel oil blended with 20% bio-oil (B20) accounted for 21%, 27% and 23%, respectively. There is also a substantial reduction for coal consumption. Developing Country-Level Deep Decarbonization Pathways and the roadmap for emission reduction in cement industry suggested that the CCS technologies for coal and gas can be become available from 2025 onwards [13]. Thus, the shares of gas using CCS and coal using CCS have become 8% and 7% in 2050, respectively. However, CCS technologies has not been available for commercialize.

Bio-energy's share substantially increases from 12% to 19% in 2050 when compared to the BAU scenario. Such an increasing can be observed that there is a large amount of biomass used for heating in all industrials types. Biomass integrated gasification combined cycle becomes a significant technologies for electric power generation after 2030. Likewise, traditional biomass mostly use for cooking in the rural area in the residential sector. However, traditional biomass has been exhaled an indoor air pollution. Since, Thailand has been proposed for improving indoor air pollution by introducing the biogas digester used in the rural area [14]. Thus, biogas consumption has gained the energy share approximately 14% of total primary energy consumption in the residential sector.

Likewise, renewable share has increased from 1% to 6% in 2050 when compared to the BAU scenario. It can be seen that the share of electricity generation from solar and wind has considerable increased by 3% and 1% of total primary energy used in 2050. Furthermore, solar water heaters are also the available option for residential sector after 2015, and accounted for 5% of total primary energy consumption.

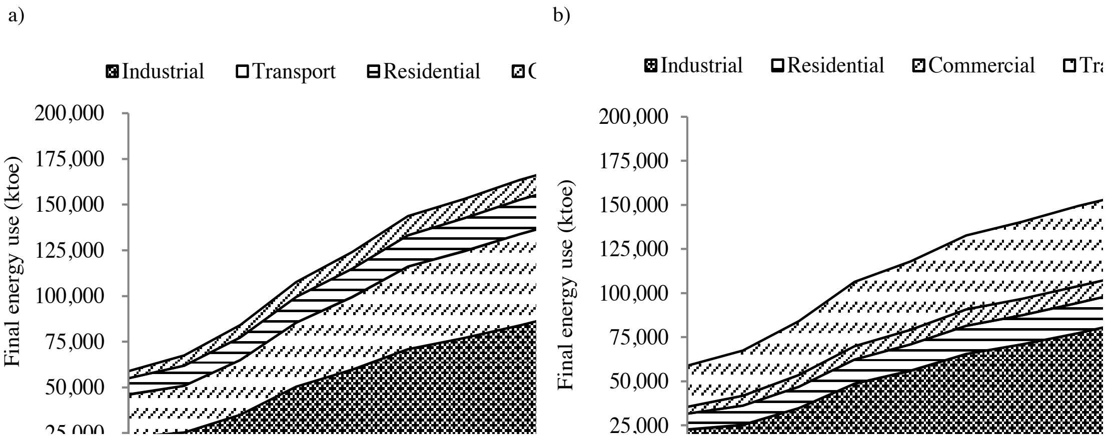

Fig. 3. Final energy consumption by sector-wise a) BAU scenario and b) PEAK CO_2 scenario.

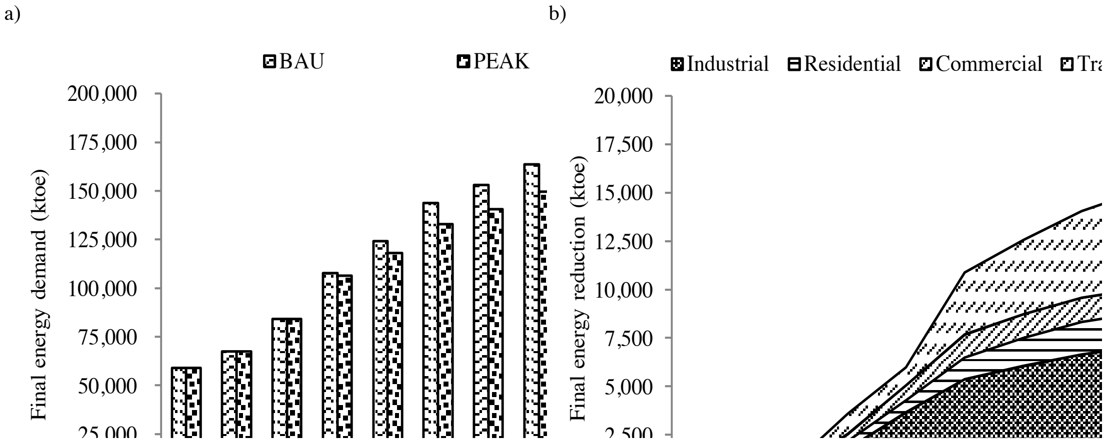

Fig. 4. a) Final energy demand in the BAU scenario and PEAK CO_2 scenario and b) Final energy reduction by sector-wise.

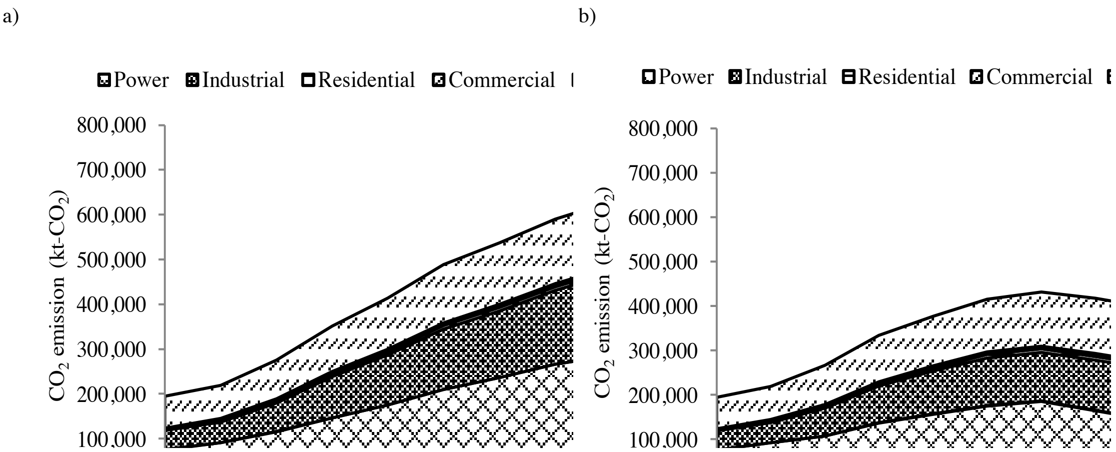

Fig. 5. Sector-wise CO_2 emission a) BAU scenario and b) PEAK CO_2 scenario.

The final energy has been reduced significantly due to the efficient improvement of electric appliances and the introduction of efficient and advanced technologies. The total final energy consumption has been reduced by 9% in 2050 when compared to the BAU scenario as shown in Fig 4a. The largest final energy reduction can be seen from the industrial sector via using efficient heating devices, bio-energy and renewable energies accounted for 46% of total final energy reduction. Likewise, the introduction of gasoline blended with ethanol and biodiesel and the mode shift from private transport to public transport could be reduced by 36% in 2050. Moreover, the efficient cooling system, lighting system and variable speed drive motors also play a vital role in savings of final energy consumption. The incandescent light bulbs have been phased out from the residential and commercial sector. The efficient cooling and cooking systems have been introduced which can reduce final energy consumption by 11% and 7%, respectively.

The implementation of CCS technologies and the introduction of energy efficient technologies mostly in the industrial sector and the residential sector can reduce CO_2 emissions by approximately 40% in 2050 (see Fig.6a) Moreover, after the deployment of CCS technologies and large proportion of bio-energy in the power sector and industrial sector mostly in chemical industry and non-metallic industry, the intensive of fuel switching from transport sector and the enforcement of efficient appliances in the residential and commercial sectors, CO_2 emissions can be met a peak in 2035, then CO_2 emissions gradually decrease until 2050. Fig.6b depicts CO_2 emissions by sector. The power sector can reduce the largest CO_2 emissions by 61% of total CO_2 reduction followed by the industrial sector (29%), the transport sector (10%) and the residential and the commercial sector (less than 1%).

4. Conclusion

Results from the AIM/Enduse model show that to achieve such an ambitious CO_2 reduction targets, Thailand needs entirely transformational changes in its energy system. It can be seen that the introduction of CCS technologies implemented after 2025 could reduce more CO_2 emissions. Nevertheless, CCS potential also has uncertainty and the technology is not mature. Thus, appropriated research and development together with sufficient research support needs to be achieved. However, CO_2 reduction also comes from introduction of efficient appliances in energy demand sectors. Promotion of bioenergy is also an important factor for achieving such an aggressive CO_2 reduction. Thailand will meet its peak CO_2 in 2035 after deployment of CCS in the power sector and the industrial sector. Energy efficient appliances in the industrial, the residential, and the commercial sectors play very important role for CO_2 reduction. Furthermore, the introduction of electric vehicles, biodiesel and gasoline blended with ethanol are the available options in the transport sector. As a result, the ambitious CO_2 reduction can be happened in the PEAK CO_2 scenario.

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a) b)

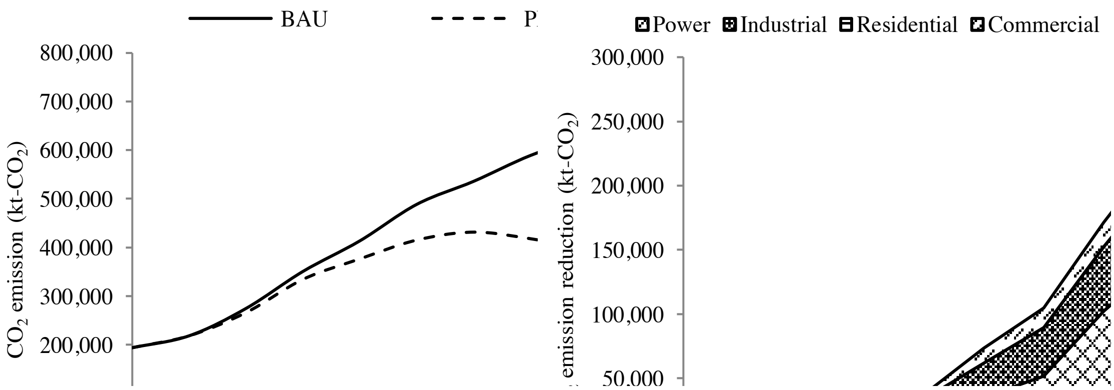

Fig. 6. CO_2 emission a) between BAU and PEAK CO_2 scenario and b) sector-wise CO_2 emission reduction.

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